Clinical Pearls in Pediatric Toxicology: A Systematic Approach to the Poisoned Child

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Toxic ingestions in children can present various clinical dilemmas. This brief article will focus on some of the key clinical pearls that will enhance the physician's ability to approach any poisoning case in a more systematic and organized fashion.

Epidemiology of Poisonings

Each year there are approximately two million poisoning cases that are reported to poison control centers throughout the United States. In 1996 there were 2,155,952 human exposure cases reported to American Association of Poison Control Centers (AAPCC).[1] This reflected a 6.6% increase in the number of cases reported as compared to 1995. The majority of all poisonings that occur throughout the country each year involve young children as victims. In fact, 52.8% (1,137,295) of the cases reported to the AAPCC in 1996 involved children less than six years of age.[1] Therefore, physicians and other health care providers who provide medical care for infants and children must possess a very solid clinical knowledge base in the assessment and management of pediatric poisonings. The peak age of pediatric poisoning cases involve children between the ages of 18 months to 3 years of age. In 1996, 47% of all poisonings reported to the AAPCC involved children 3 years of age and younger.[1]

During the 1996-1997 fiscal year, the Hawaii Poison Center (HPC) received a total of 11,963 calls; 8,666 (72.4%) of these calls involved actual human exposure cases.[2] The epidemiology of poisonings here in Hawaii is not very different from that of the rest of the United States. Last year 45% (3,442) of the human exposure cases involved children 5 years of age and younger.[2]

Seventy-five percent of all poisonings both here in Hawaii and on the mainland involve ingestions as the primary mode of exposure.[2] The other routes of exposure include dermal contact, inhalations, ocular exposures and envenomations. Therefore, because oral exposure is by far the most common route of poisoning, this article will focus primarily on the initial assessment, stabilization and management of toxic ingestions.

Initial Assessment and Stabilization of Poisoning Cases

The priorities in the initial assessment and stabilization of any poisoning case involves the standard "A-B-C's" of emergency medicine. Regardless of the substance that was ingested, the initial priorities in the management of any poisoned child involves the assessment and stabilization of the child's Airway, Breathing and Circulation. Along with the stabilization of these three key physiologic elements, one must also stabilize any Seizures that may be an associated symptom caused by the ingested toxin or medication. Once the child has been stabilized from the standpoint of airway, breathing, circulation and seizure control, then one can address the specific toxicologic issues involved in the individual case;

a) History of the poisoning
b) Toxicologic physical examination
c) Laboratory studies
d) Gastrointestinal decontamination options

History of the Poisoning

The three essential questions which must be addressed in all poisoning cases are WHAT, WHEN and HOW MUCH:

a) What substance(s) was ingested?
b) How much of each substance(s) was ingested?
c) When did the ingestion take place?

The answers to these three questions will help you to address other clinical issues such as: a) the severity of the ingestion, b) the potential benefits of gastrointestinal decontamination, c) whether or not other therapeutic interventions will be necessary, d) interpretation of specific drug levels and e) disposition of the patient.

Perhaps the most difficult question for parents to answer regarding their child's ingestion is exactly how much their child may have ingested. Being able to estimate how much of a liquid a child drank or how many pills were ingested is extremely important in determining the potential severity of the ingestion. Determining the potential severity of a given ingestion will then determine how aggressive one should be in the further management of a poisoned child. However children who present with severe signs and symptoms will obviously require aggressive stabilization, decontamination and man-

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Table 1.—Dr Al's Weights based on Age Formula

1 year old	→ 10 kg
3 year old	→ 15 kg
5 year old	→ 20 kg
7 year old	→ 25 kg
9 year old	→ 30 kg
11 year old	→ 35 kg
13 year old	→ 45 kg
15 year old	→ 55 kg
17 year old	→ 65 kg

Table 2.—Key Elements of The Physical Exam

Eyes; Pupillary size, symmetry and response to light
Presence of any nystagmus (vertical and/or horizontal)
Oropharynx; Moist or dry mucus membranes
Presence or absence of gag reflex
Presence of any peculiar odors to the patient's breath
Abdomen; Presence or absence, and quality of bowl sounds
Neurologic; Level of consciousness and mental status
Presence of tremors, seizures or other movement disorders
Deep tendon reflexes (normal reflexes, hyperreflexia or hyporeflexia)
Skin; Warm and dry, warm and moist, or cool

agement. Children who present asymptomatic or with fairly mild symptoms may still also require an aggressive management approach if the amount (in terms of mg/kg) ingested is calculated to be a potentially toxic quantity. It is always safer to assume the worse clinical scenario in any given case rather than to make the mistake of guessing that a child probably didn't ingest very much of a given substance or medication.

For example, if a mother states that she just discovered her two children (ages 2 and 3-years-old) playing with an empty bottle of Tylenol children's chewable tablets, what specific questions should you ask to determine if a potentially toxic amount of the Tylenol was ingested? How do you estimate the potential toxicity for each child (especially when children rarely will give you an accurate account of exactly how many tablets each of them ingested)?

a) **WHAT?** Exactly which Tylenol product did these children ingest? Because there are several types of Tylenol tablets that are available for children, one must determine exactly which product the children ingested.

Answer: 80 mg grape-flavored Tylenol chewable tablets.

b) **HOW MUCH?** Determining exactly how many tablets were ingested in a case such as this can be some what tricky. Parents very rarely know exactly how many tablets were in the bottle when a child gets a hold of a medication. Therefore specific questions which should be asked in order to determine the worse possible case scenario include; When did the parents purchase the Tylenol? How many tablets where in the bottle at the time they purchased the Tylenol? How many tablets did they use since they purchased the product? How many remaining tablets did they find either in the bottle or around the children?

Answers: The bottle originally contained 30 tablets when the parents purchased the Tylenol 2 weeks ago. They remember using 2 tablets to treat a fever in their 2-year-old child approximately 2 weeks ago. There are no tablets remaining in the bottle and the parents did not find any tablets around the area in which they discovered the children playing with the Tylenol bottle. Therefore, if we assume the worse case scenario, there are 28 tablets (a total of 2,240 mg) that are unaccounted for in this case. Although an acute ingestion of more than 6 grams is the potentially toxic amount in an adult, ingestions of more than 140 mg/kg are potentially toxic in children. Whenever there is more than one child involved in a possible ingestion case, the physician should assume that one child ingested the entire amount of tablets that are unaccounted for. Thus, one needs a method to estimate the weight of a child based on the child's age. A very simple and easy to remember formula that I have published which has become referred to as, "Dr Al's weights based on age formula," is as follows:[3] (see Table 1)

According to this formula, start with a 1-year-old at 10 kg, then for every odd-numbered year simply increase the child's weight by 5 kg. After age 11 years, increase the weight by 10 kg for every odd numbered year (to take into account the growth spurt that occurs during the adolescent years). Therefore if we use 12 kg as the estimated weight for a 2-year-old and 15 kg as the estimated weight for a 3-year-old, the potential amount of Tylenol ingested by the 2-year-old child would be 187 mg/kg (assuming that this child ate all 28 of the Tylenol tablets). Similarly, the amount of Tylenol that the 3-year-old child may have ingested would be 149 mg/kg (assuming that the 3-year-old child ate all 28 of the Tylenol tablets). Therefore, based on these calculations both children may have ingested a potentially toxic amount of Tylenol and will therefore require further action.

c) **WHEN?** Knowing the exact time that the children may have ingested the Tylenol tablets will help the clinician decide whether or not too much time has already elapsed for any attempts at gastrointestinal decontamination to be effective. The time of the ingestion is also essential in knowing where to plot the measured serum Tylenol levels on the Rumack-Matthew nomogram. For example, is a serum acetaminophen level of 100 mcg/ml potentially hepatotoxic? Without knowing the exact time of the ingestion, this serum level in itself may be absolutely meaningless. If this level was obtained 4 hours post-ingestion, a 100 mcg/ml is not a potentially hepatotoxic amount. However, if this level was obtained 8 hours post-ingestion, then this exact same value of 100 mcg/ml would be a potentially toxic level which would require N-acetylcysteine therapy.

The Toxicologic Physical Examination

Toxic ingestions in children present as one of two possible scenarios. The first scenario is that of a child who presents with a history of a witnessed or suspected ingestion. The second scenario

Table 3.—Five Distinct Toxidromal Cases

1. Anticholinergics (ex; atropine, antihistamines, tricyclic antidepressants, etc...)
   Tachycardia, hypertension, mydriasis, agitation, hallucinations/delirium, seizures, hypoactive bowel sounds, warm/dry skin and dry mouth
2. Sympathomimetics (ex; amphetamines, cocaine, theophylline, phenylpropanolamine, PCP, etc...)
   Tachycardia, hypertension, mydriasis, agitation, hallucinations/delirium, seizures, hypoactive bowel sounds, warm/moist skin
3. Cholinergics (ex; organophosphates and carbamates)
   "DUMBLES:"
   D = Defication
   U = Urinary incontinence
   M = Miosis
   B = Bronchospasm, bronchorrhea & bradycardia
   L = Lacrimation
   E = Emesis
   S = Salivation
4. Opiods (ex; codeine, morphine, meperidine, heroin, etc...)
   Bradycardia, hypotension, bradypnea, pinpoint pupils, euphoria, hyporeflexia and hypothermia
5. Sedative hypnotics (ex; ethanol, benzodiazepines, barbiturates, etc...)
   Bradycardia, hypotension, bradypnea, ataxia, miosis and hypothermia

Table 4.—"MUDPILES"

M = Methanol
U = Uremia
D = DKA
P = Paraldehyde
I = Iron, isoniazid & ibuprophen
L = Lactic acidosis (ie; carbon monoxide, cyanide, and various other causes of lactic acidosis)
E = Ethanol & ethylene glycol
S = Salicylates

is that of a child who presents with a constellation of signs or symptoms which may include a possible toxic ingestion within the differential diagnosis. For example, a previously healthy 2-year-old child who presents to the emergency department after experiencing an afebrile seizure should have the possibility of a toxic ingestion included in his differential diagnosis, along with the possibility of head trauma and various other causes of seizures.

Every element of a patient's vital signs should be closely analyzed in all poisoning cases. When confronted with a poisoning victim, although many clinicians usually remember to look for any derangements in a patient's heart rate, respiratory rate and blood pressure, many physicians forget to consider whether the toxic ingestion may have affected the patient's body temperature. Closely analyzing a patient's vital signs may also give the clinician a clue of what the ingested substance might be in the case of an unknown ingestion.

Although a complete physical examination is necessary in all children who have ingested a toxic substance, there are some key elements of the physical examination which may provide valuable clues in the case of an unknown ingestion (See Table 2)

In cases when an unknown substance was ingested or if the possibility of a toxic ingestion is included in the differential diagnosis, strict attention to the presenting vital signs and the key elements of the toxicologic physical examination as listed above, may provide the clinician with valuable clues as to what class (or type) of medication may have been ingested. The term "toxidrome," refers to a specific constellation of signs and symptoms which may be suggestive of a specific class (or type) of toxic substance. There are five distinct toxidromal classes (See Table 3).

Laboratory Studies

The laboratory studies that are ordered will of course vary depending on the type and severity of the ingestion. Although toxicologic screens of blood and urine and specific drug levels may be obtained, the results of these studies will be of no value in the initial stabilization and management of each poisoning case. In cases where a patient presents after an intentional overdose some of the standard recommended laboratory studies include: toxicologic screens, serum acetaminophen level, serum salicylate level, EKG rhythm strip and a pregnancy test.

In cases of an unknown or suspected poisoning, the anion gap may be useful in determining the possible toxicologic substance. The anion gap is determined by the formula:

$$Na - [Cl + C02]$$

The normal anion gap in pediatrics is equal to 8-12 mEq/Liter. If a patient exhibits metabolic acidosis, the anion gap may provide clues as to the etiology of the metabolic acidosis. The differential diagnosis of an increased anion gap metabolic acidosis can be remembered by the mnemonic of "MUDPILES" (See Table 4).

Another very useful laboratory value is the measured serum osmolality and the serum osmolar gap. The patient's serum osmolality can be calculated via the formula:

$$2 \times [Na] + [BUN / 2.8] + [glucose / 18]$$

Based on this calculated formula the only three elements in the serum which are taken into account in calculating the serum osmolality are the patient's serum sodium, BUN and glucose. In contrast to this calculated formula, when the laboratory actually measures the patient's serum osmolality, other substances in the patient's blood which could potentially elevate the serum osmolality are also taken into account. Substances that typically elevate the measured serum osmolality include the alcohols (ie; ethanol, ethylene glycol, isopropyl alcohol and methanol).

The serum osmolar gap (which is normally <5-10 mosm/Liter) is determined by the formula:

[measured serum osmolality] - [calculated serum osmolality]

The value of the serum osmolar gap can be used to predict a patient's blood ethanol level via the formula:

[serum osmolar gap] x [4.6] = ethanol level (mg/dL)

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Gastrointestinal Decontamination Recommendations

Currently there are five gastrointestinal decontamination (GID) options available to clinicians:

Syrup of ipecac
Gastric lavage
Activate charcoal
Cathartics
Whole bowel irrigation

Based on data from the AAPCC, there has been a decreasing trend in the use of syrup of ipecac. Nationally, ipecac was used in only 1.8% of all exposure cases in 1996, as compared to ten years ago when ipecac was utilized in 13.3% of the exposure cases.[1] Here in Hawaii (especially in and around the Honolulu area) poisoning victims are usually only within 30 minutes from the nearest emergency department. Therefore because of this unique proximity to emergency departments and more efficient, quicker methods of gastrointestinal decontamination, currently ipecac is very rarely used as a decontamination method. The only place where ipecac would have a clear cut benefit is for patients who live in remote areas who would have long transportation times to the nearest emergency department.

Gastric lavage has several major advantages over ipecac as an option for gastric evacuation. Lavage allows for a quicker and a more controlled method to remove toxins from a patient's stomach as compared to ipecac. Patients who undergo gastric lavage are less likely to vomit activated charcoal as compared to those patient's who may have protracted bouts of emesis after ipecac administration. Under the conventional method of performing lavage, the physician would perform lavage "until clear," and then activated charcoal would be administered down the lavage tube. A newer method of gastric lavage which can be utilized in more severe ingestion cases calls for a sequence of "charcoal-lavage-charcoal." The major rationale for this alternative method of lavage is that the first dose of plain activated charcoal is administered (5-10 minutes prior to starting the lavage procedure) to rapidly start adsorbing the toxins throughout the gastrointestinal tract (especially those toxins that are already distal to the stomach and therefore would not be able to be evacuated by the lavage procedure).

Gastric lavage's main limitation (especially in the pediatric patient) is that the internal diameter of the lavage tube must be large enough to accommodate pill fragments. A Tylenol gelcap will barely fit through a 32 French lavage tube. A whole tablet of either a regular strength Tylenol tablet or an Advil tablet will not fit through the narrow lumen of a 32 French tube. Another limitation of both gastric lavage and syrup of ipecac is that both of these methods of gastric decontamination will only remove toxins and substances from the stomach. Toxins that are distal to the stomach cannot be evacuated with either of these two methods of gastrointestinal decontamination.

Activated charcoal is extremely effective in adsorbing a wide variety of substances throughout the gastrointestinal tract. The majority of the charcoal preparations on the market today (ex; Actidose, Liquichar, etc...) have adsorptive surface areas of 1,000 square meters per gram of charcoal. Some of the newer "super" adsorptive preparations (ex; CharcoAid 2000) reportedly have up to 2,000 square meters of adsorptive surface area per gram of charcoal.

Table 5.—CHEMICaL CamP

C	=	**C**yanide
H	=	**H**ydrocarbons
E	=	**E**thanol & other alcohols
M	=	**M**etals
I	=	**I**ron
Ca	=	**Ca**ustics
L	=	**L**ithium
Cam	=	**Cam**phor
P	=	**P**otassium

Because activated charcoal is able to prevent systemic toxicity by effectively binding so many different toxins, many poison control centers throughout the country, have recently been recommending administration of activated charcoal alone (without first performing gastric lavage) in ingestion cases of moderate severity.

Because activated charcoal is so effective in adsorbing such a wide variety of toxins it has often times been referred to as the "universal antidote." However there are several instances where activated charcoal will not be very effective in preventing systemic toxicity. The nine ingestion scenarios in which activated charcoal may not be useful can be remembered by my mnemonic of "**CHEMICaL CamP**:"[4]

Activated charcoal is not very effective in adsorbing ethanol (and the other alcohols), metals, iron, caustics, lithium and potassium. Even though charcoal has a very low affinity for cyanide, it may still be effective in preventing systemic toxicity if the amount of cyanide ingested is within the 100-500 mg range. Although activated charcoal is not necessary for ingestions of plain hydrocarbons, it should be considered if the ingested hydrocarbon contains systemic toxins (ie; aromatic and halogenated compounds). Although activated charcoal is very effective at adsorbing camphor, charcoal administration may not be very effective by the time that the patient arrives in the emergency department. Because the majority of camphor-containing products are of a liquid preparation, the ingested camphor is typically very quickly and completely absorbed. Therefore by the time that the patient arrives in the emergency department there may not be any camphor remaining in the gastrointestinal tract to be adsorbed by the activated charcoal.

Multiple doses of activated charcoal (without cathartics) may be used as a method of "intestinal dialysis" for certain drugs that undergo enterohepatic circulation (ie; theophylline, carbamazepine, tricyclic antidepressants, phenobarbital and digoxin).

Cathartic agents by themselves are not a very effective means of gastrointestinal decontamination. The major role of cathartics is to more quickly eliminate the charcoal-bound toxins from the gastrointestinal tract before the toxins have the opportunity to dissociate from the activated charcoal. Sorbitol is probably the most utilized of the cathartics because of it's rapid GI transit time and the convenient fact that it comes in combination with activated charcoal in premixed amounts ranging from 27-48 grams per 120 cc bottle of charcoal. Sorbitol can be safely used in children as long as it is administered only once per 24 hours and stool output in very closely monitored.

Whole bowel irrigation (WBI) is a method of utilizing high

volumes of iso-osmotic fluids to eliminate toxins from the GI tract. The major advantages of WBI include it's ability to eliminate toxins from the GI tract that are not effectively adsorbed by activated charcoal. Because of this advantage WBI has become the GI decontamination method of choice for significant iron and lithium overdoses. Unlike the limitations of ipecac and gastric lavage, WBI has the advantage of being able to eliminate toxins that are distal to the stomach. The two iso-osmotic solutions that are currently recommended for WBI are GoLytely and CoLytely. Adults and teenagers are given 1-2 liters/hour of either solution via a nasogastric tube until the rectal effluent is clear. The recommended rate for WBI in children is 25 cc/kg/hour (up to 500 cc/hour). Typically WBI requires approximately 4-6 hours to achieve a clear rectal effluent.

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